ENGINEERING TEST REPORT

ETR - 924

TITLE:	Test Results of the RAH-66 Main Rotor Ballistically Damaged Flexbeam
DATE:	4 August 1997
A/C SERIES:	RAH-66
A/C MODEL:	RAH-66 Prototype
SYSTEM:	Main Rotor
CHARGE NO:	CB571-300
CONTRACT NO:	DAAJ02-97-M-0001

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SUMMARY

The AATD supplied, ballistically damaged, RAH-66 main rotor blade flexbeam was tested in fatigue to demonstrate fly home capability. The testing was conducted in the Bearingless Main Rotor test facility, and consisted of loads representative of 45 degree AOB turns at Vibratory test loads including flatwise, chordwise and torsional moments, centrifugal load and snubber/damper loads. The requirement was to demonstrate 30 minutes capability. The results demonstrated a total of 90 minute flight capability of the ballistically damaged flexbeam, thus exceeding the 30 minute fly home capability requirement.

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1.0 SCOPE

1.1 PURPOSE

The purpose of this test was to demonstrate the structural capability of a ballistically damaged RAH-66 flexbeam to react Vibratory flight loads for a duration of 30 equivalent flight minutes. This was accomplished through dynamic flatwise, edgewise and torsional loading of a full scale ballistically damaged flexbeam.

1.2 BACKGROUND

The COMANCHE main rotor system is a five-bladed, bearingless design, Ref. Figure 1 thru 3. In this design each of the blades is retained by a flexible composite beam (flexbeam). The flexbeams attach to the main rotor hub plates and to the inboard ends of the five blades. The flexbeams accommodate the flapping, lead/lag, and pitch change motions of the blades through elastic bending and twisting.

One flexbeam, S/N 0044, was ballistically damaged by AATD, ref. figures 5 thru 9. Since the US Army test fixture is not capable of applying combined test loads, Sikorsky was contracted to perform the testing per DAAJ02-97-M-001.

2.0 APPLICABLE DOCUMENTS

2.1 CONTRACT

2.1.1	DAAJ02-97-M-0001	RAH-66 Flexbeam Fatigue Test

2.2 DRAWINGS

2.2.1	T2010-01030	BMR Test Facility
2.2.2	02010-12201-041	Flexbeam Assembly, Blade Retention Assembly-Rotor Wing Head
2.2.3	T2010-01029	BMR Machine, Actuator Assembly-Snubber Damper

2.3 ESM's

2.3.1	ESM-F1-4003	General Requirements for Inspection of Test Installations
2.3.2	ESM-F1-2005	General Requirements for Conduction Ground Tests by Stratford Test

3.0 PROCEDURES

The ballistically damaged RAH-66 Comanche flexbeam was fatigue tested in the Reference 2.2.1 test facility, Figure 9 & 10. This facility is designed to test two specimens simultaneously. The second specimen, S/N 0001, is not considered a test specimen and was mounted in the facility to allow testing of the ballistic flexbeam, S/N 0044. The flexbeam specimens were mounted in a facility hub 180 degrees apart as shown in Figure 9. The facility hub is representative of the aircraft hub in the flexbeam attachment area. A dummy quill shaft flange was included in the hub assembly to assure proper loading of the inboard flexbeam attachment bolts. The outboard ends of the flexbeams were attached to facility spindles which provided centrifugal force through the use of a pneumatic bellows arrangement, and torsional pitching moment through the use of an electrically controlled hydraulic rotary actuator. The facility provided flatwise shear by raising the center carriage vertically. Flatwise moment was produced by rocking the center carriage about the flapwise axis. The edgewise moment was produced by translating the center carriage horizontally. Both the flatwise and edgewise motions were imparted to the flexbeams through the use of electronically controlled hydraulic actuators. An electronic cycle counter monitored the number of test cycles applied to the specimens. Snubber/damper preload was simulated through a mechanical clamping assembly, and the vibratory damper chordwise shear loads were simulated through an electronically controlled hydraulic actuator.

The S/N 0044 flexbeam was instrumented at AATD with the bending bridges shown in Figure 4. Since the ballistic damage made the centerline flatwise bending bridges inoperative, secondary flatwise bending bridges were installed slightly offset chordwise.

The S/N 0044 flexbeam was calibrated at AATD. Subsequent to Sikorsky receiving the flexbeam, inconsistencies were found in the calibration factors calculated at AATD. With AATDs concurrence Sikorsky recalibrated flexbeam flatwise bending bridges at stations 26 and 29 and edgewise bending bridges at stations 26 and 32, 35, 38, and 48.5. The remaining flatwise bending bridges were measured in terms of true bending strain.

A computerized control and measurement unit (CAMU) was used to measure and record all instrumentation parameters. All bridges and gages were probed in order to verify direction and location prior to testing.

Instrumentation data was monitored continuously and periodically recorded to paper copy and disk for permanent storage. A chronological test log was maintained to record problems, maintenance, inspections, witnessing and all other pertinent events and observations.

Flatwise, edgewise and torsional flexbeam bending loads, snubber/damper in-plane and out of plane loads as well as steady centrifugal loads were applied to the S/N 0044 flexbeam test specimen. The S/N 0001 specimen reacted only flatwise, edgewise and centrifugal loads. The phasing of the individual loads as well as the flatwise to edgewise and torsion ratios was representative of a worst case condition expected in flight

Sign Convention :
+ Pitch = Leading Edge Up
+ Edgewise Bending = Blade Fwd (Leading Edge in Compression)
+ Flatwise bending = Flap Up (Upper Surface in Compression)
Note: Flexbeam mounted inverted in test facility

Blade Loads:
Max. Flap Up occurred in phase with Max. Blade Forward and Max. Pitch Up
(i.e. +NB occurs with + EB and + Pitch)

Snubber Damper Loads:
The total snubber damper shear load consists of a combination of the load resulting from the elastic deflection of the elastomer and the load resulting from the internal fluid damping. The resultant snubber damper shear load acting on the flex beam is at a 180 deg lag phase shift with respect to the flapping baseline. (i.e. Flexbeam EB Forward occurs with Damper Chordwise Shear Load Aft)

Test Specimen
The ballistic damage of the S/N 0044 flexbeam is located at the inboard transition area. The projectile entered the flexbeam lower surface and exited through the upper surface approximately 13 inches from the root end, Ref. Figures 5 & 6. There was a heaping of delaminated and broken plys 1 inch tall, tapering down to 0.100" high, Ref. Figure 6. A crack extends from the center of the impact hole inboard 13" and outboard 17 1/2", Ref. Figures 8, 9 & 12.

The S/N 0044 flexbeam was fatigue tested at a constant amplitude. Measured flight load flexbeam station 12.5 (inch) data was correlated to measured flexbeam station 26 (inch) data. These correlations were used to convert the vibratory analytical load predictions at flexbeam station 12.5 for a 45 degree AOB turn at 0.9 Vh to station 26 since flight data was not available for 0.9 Vh 45 deg AOB turns. The first load level duration (cycles) represents 30 minutes in-flight at 100% Nr. Once complete, the test loads were increased linearly by 20% and an additional 60 minutes was demonstrated.

4.0 RESULTS

TABLE 1
RAH-66 MAIN ROTOR BALLISTICALLY DAMAGED FLEXBEAM
FATIGUE TEST DATA

Test Level	Edgewise EB-4(Sta. 26) in-lbs	Flatwise NB-4(Sta. 26) in-lbs	Pitch deg	Damper Shear lbs	Damper Compressive lbs	Centrifugal 107% NR lbs	Cycles	Notes
1	15500 ± 27000	4500 ± 8600	+4.9 ± 14	220± 160	2300	61600	10600	30 equiv. min.
2	13400 ± 32400	4500 ± 10300	5.0 ± 16.7	280± 220	2400	61600	21200	60 equiv. min.

Note: The steady flatwise and chordwise moments are based on analytical predictions for a 2g maneuver.

5.0 DISCUSSION OF RESULTS

Refer to Figure 12 for discussion below.

During the first test level, the crack propagated 7.5" outboard to a total length of 38". A second crack parallel to the first started and propagated 8.7" inboard and 34.4" outboard to a total length of 43.1"

During the second test level, the first crack propagated an additional 7.4" outboard and 0.3" inboard to a total length of 45.7". The second crack grew an additional 2.2" inboard to a total length of 45.3". A third crack started and propagated to 10.3" inboard and 6.5" outboard to a total length of 16.8".

6.0 CONCLUSIONS

The test successfully demonstrated the structural capability of the RAH-66 Comanche main rotor flexbeam to react flight loads equivalent to a 45 degree AOB turn at 0.9 Vh for 30 minutes, thus meeting the contractual requirement of Reference 2.1.1.

The flexbeam demonstrated additional capability by successfully reacting vibratory loads representative of 1.2 x the 45 deg AOB magnitudes for 60 equivalent flight minutes without loss of load carrying capability.

7.0 RECOMMENDATIONS

A test or analysis to assess the change of dynamic response, and its stability impact, of the flexbeam due to ballistic damage and crack growth is recommended.

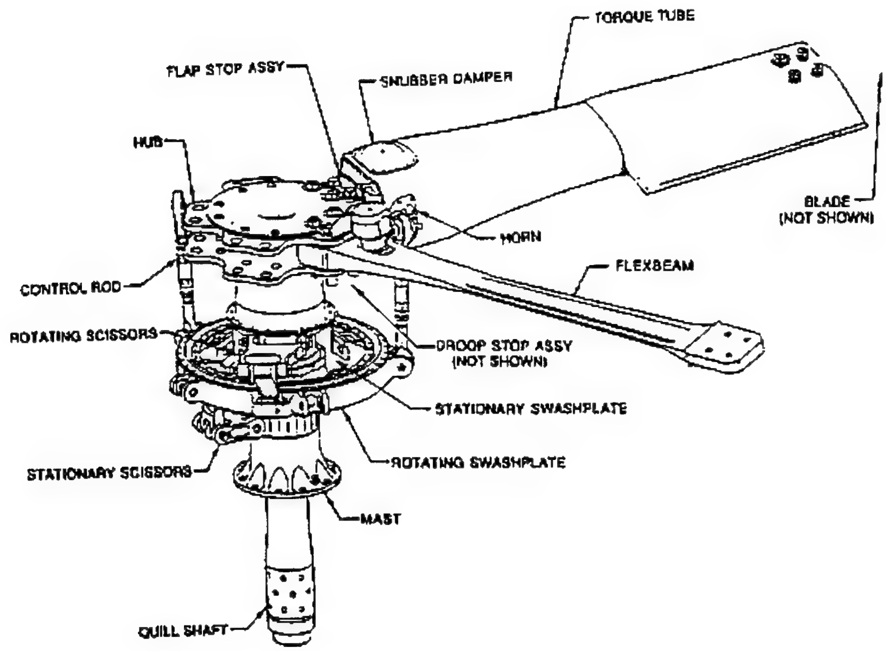

Figure 1 RAH-66 COMANCHE Main Rotor System

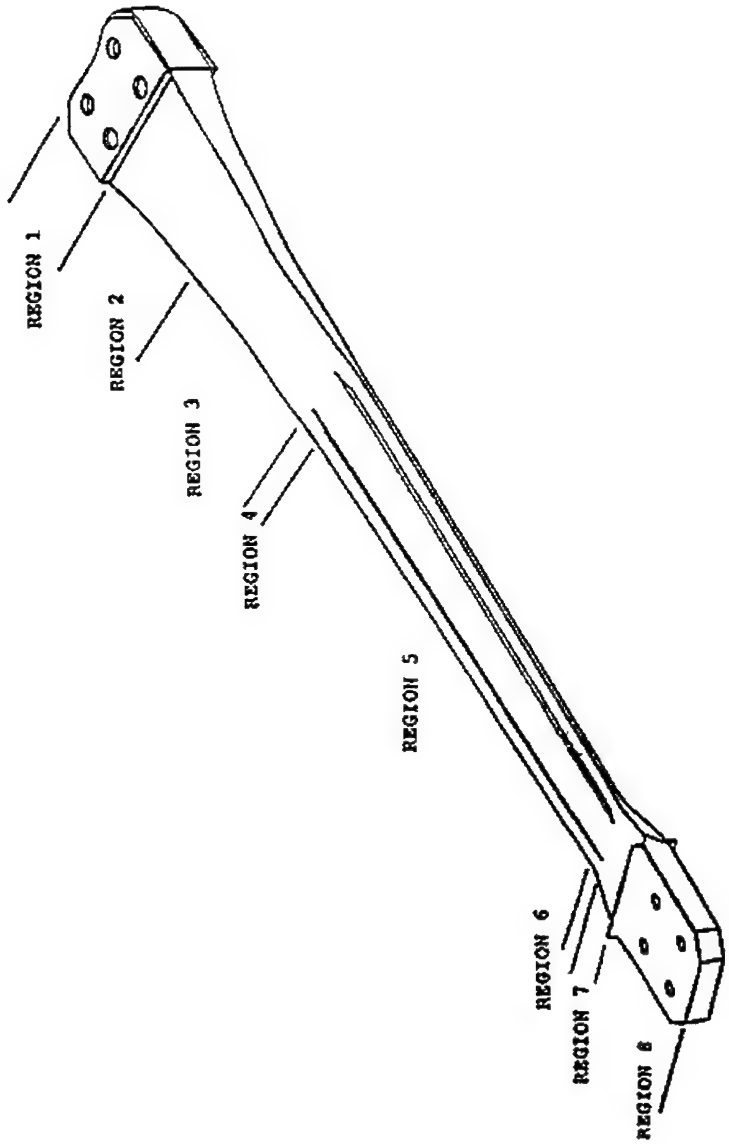

Figure 2 RAH-66 COMANCHE Main Rotor Flexbeam

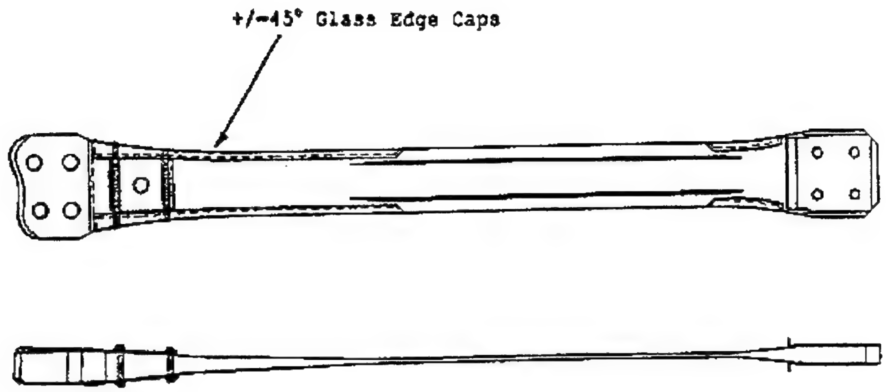

Figure 3 RAH-66 COMANCHE Main Rotor Flexbeam Top and Side Views

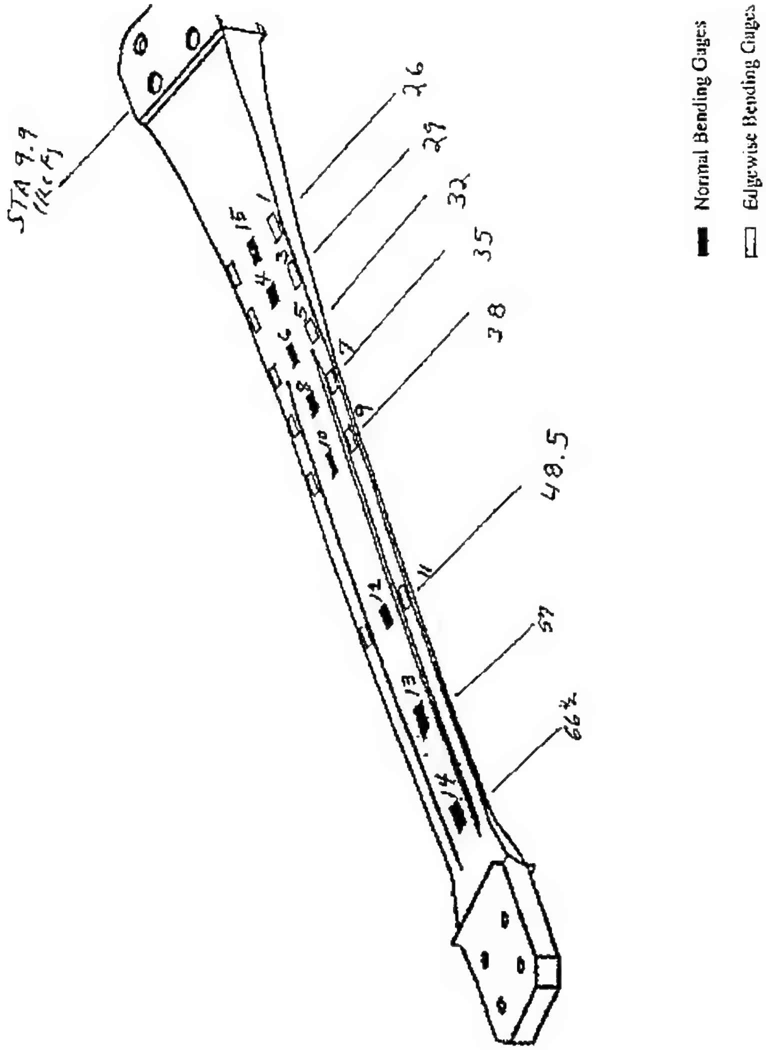

Figure 4 Ballistically Damaged Flexbeam S/N 0044 Instrumentation

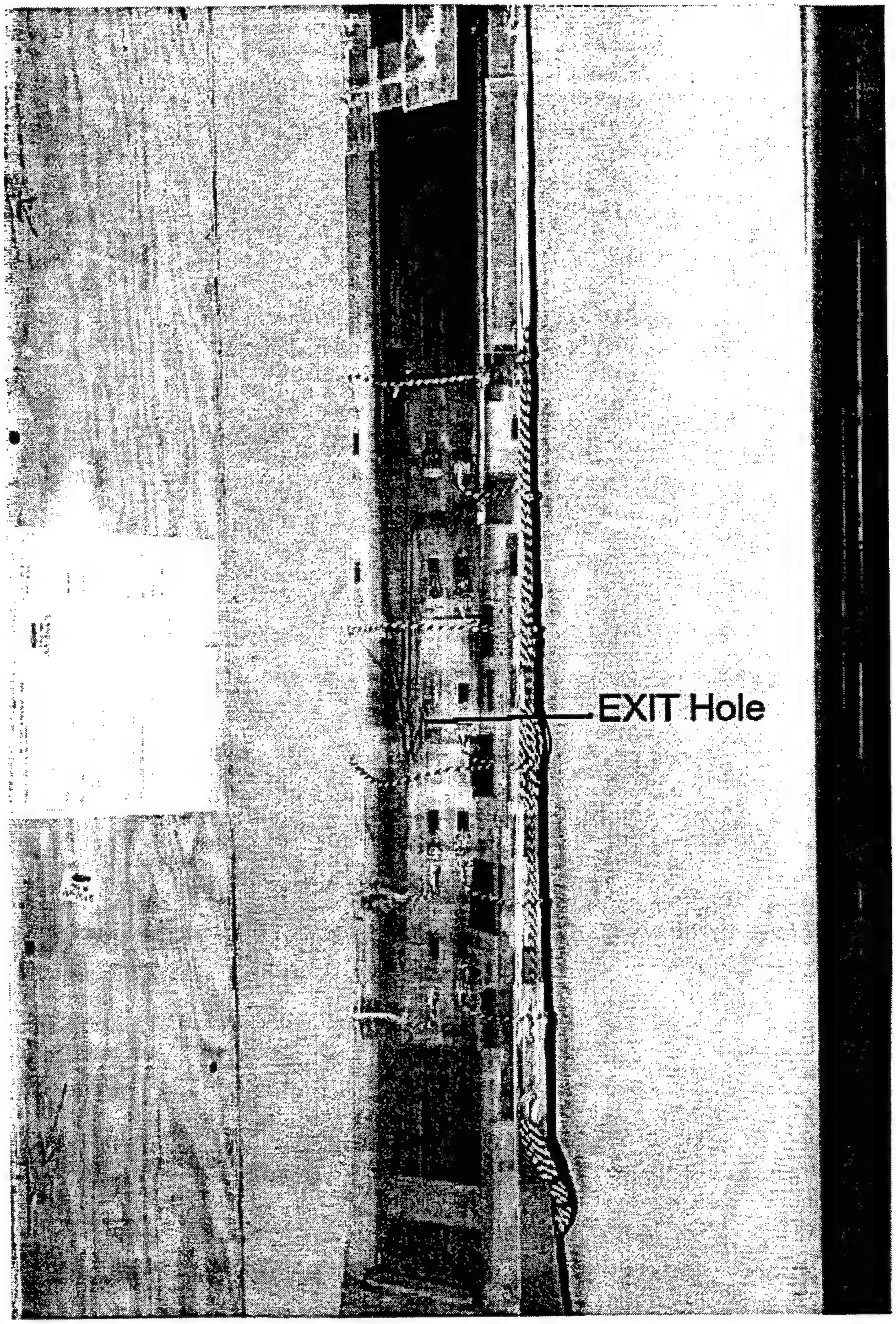

Figure 5 Ballistically Damaged Flexbeam Topside View

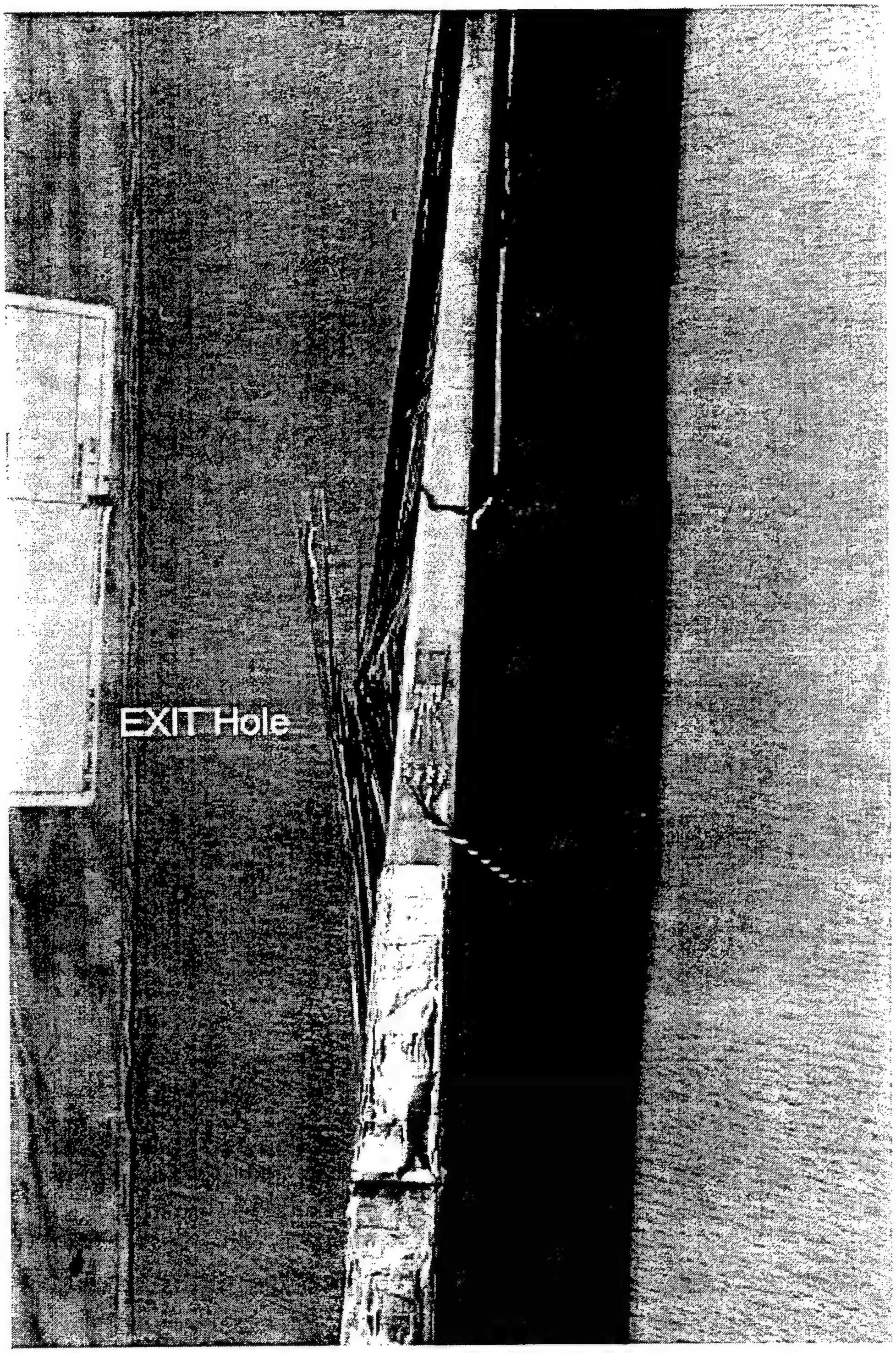

Figure 6 Ballistically Damaged Flexbeam Edgewise View

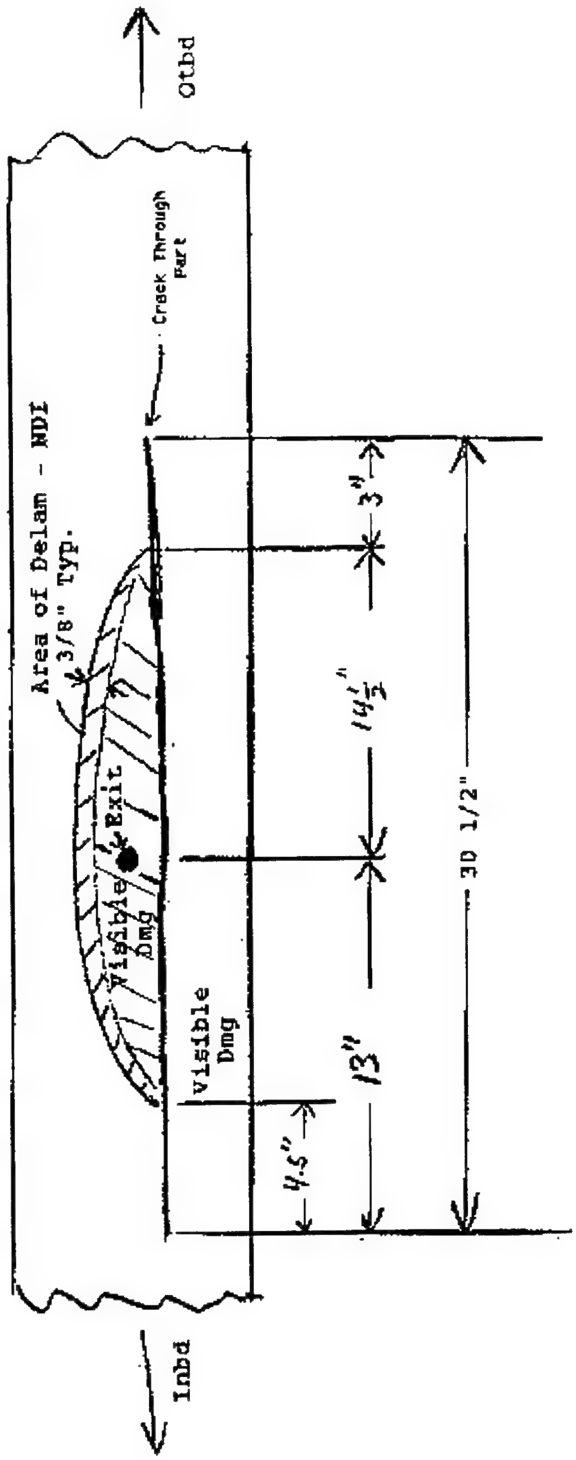

Figure 7 Damage Due to Impact

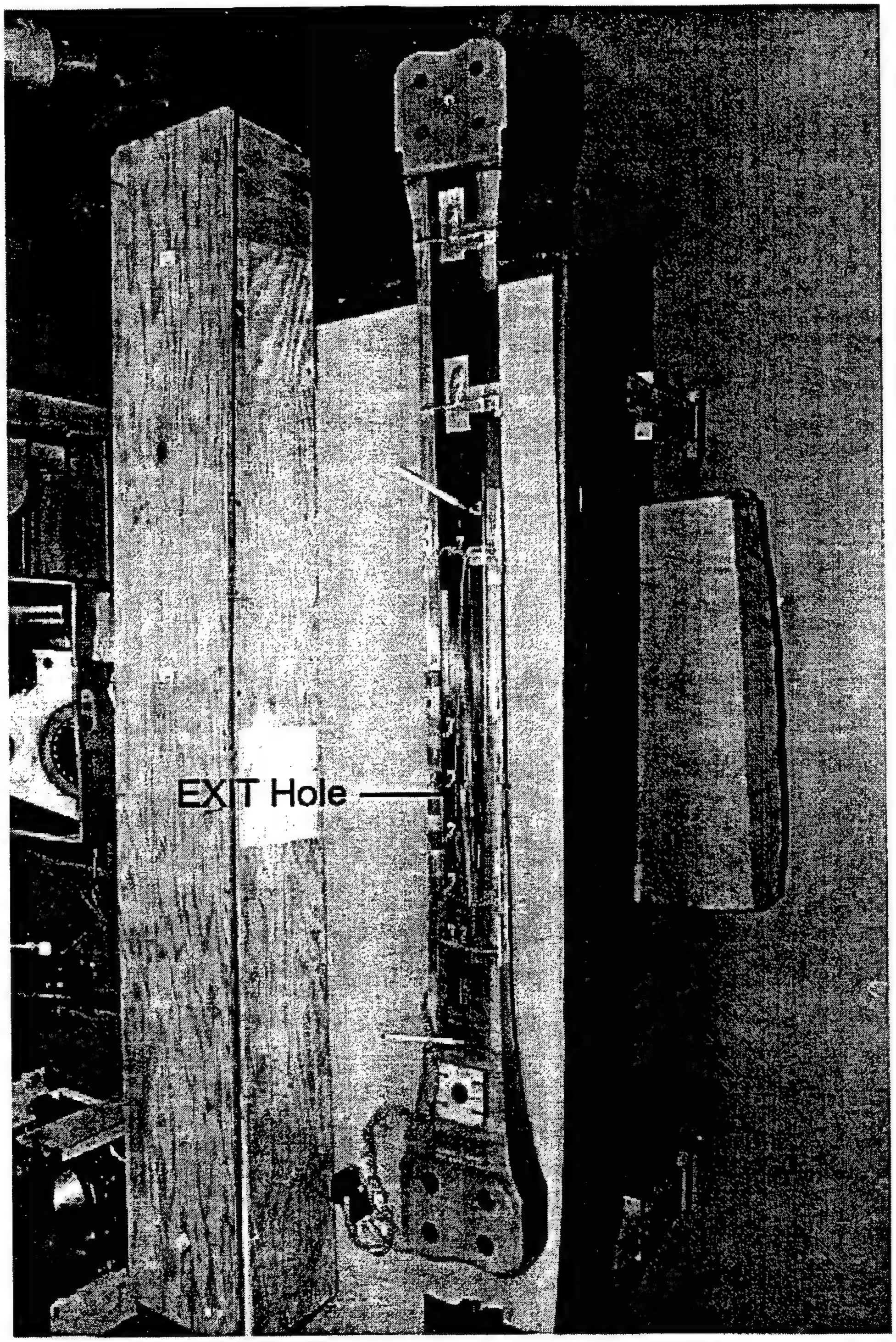

Figure 8 Ballistically Damaged Flexbeam Crack due to Impact Damage

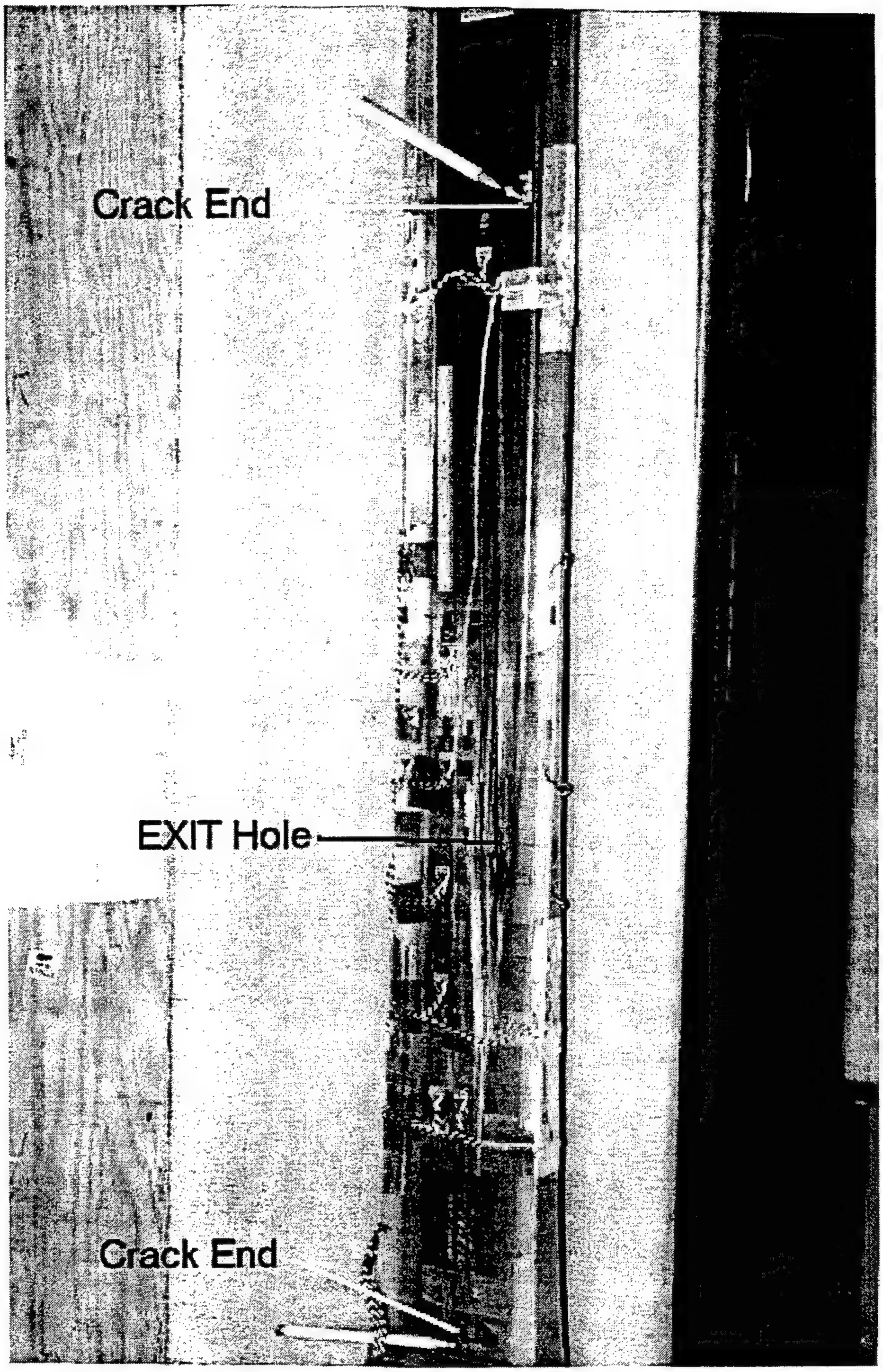

Figure 9 Ballistically Damaged Flexbeam Close-up View of Crack

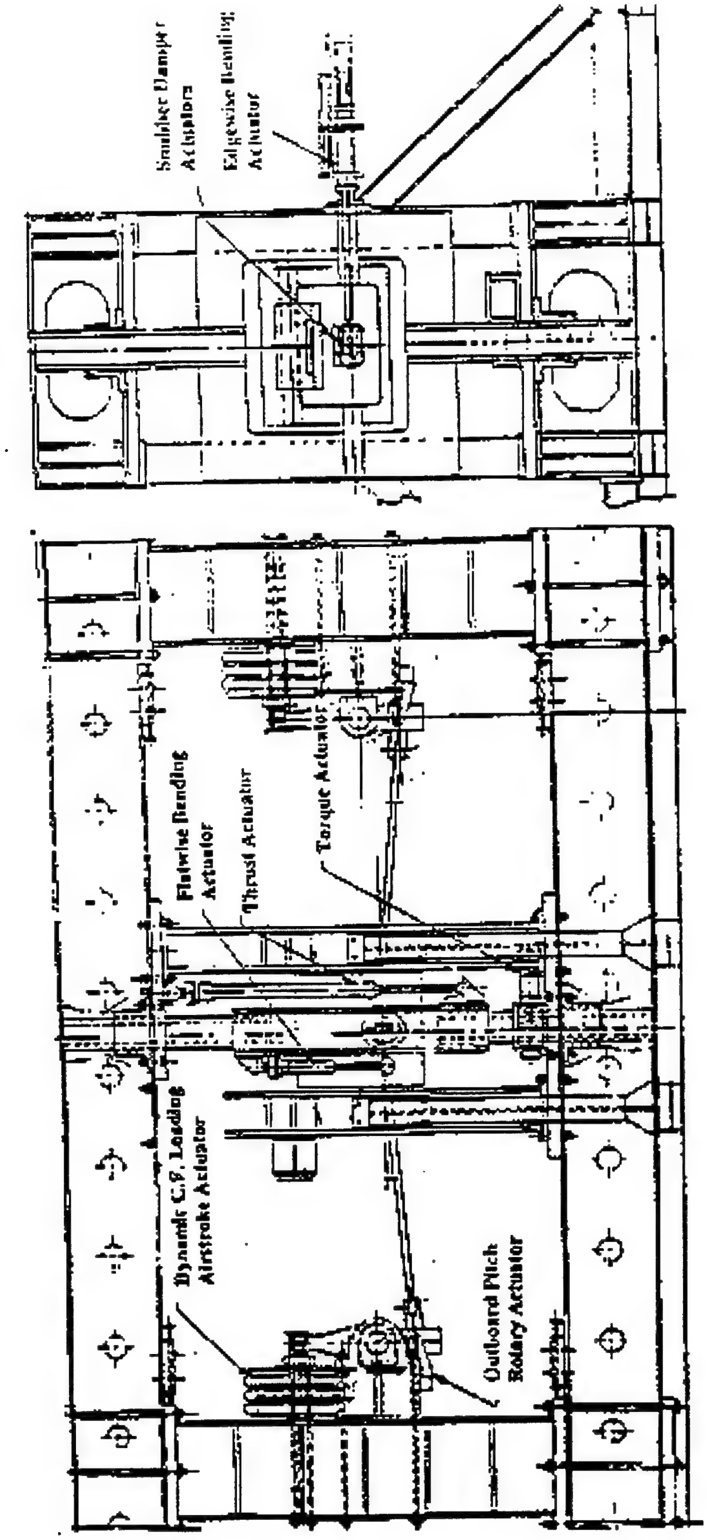

Figure 10 Sketch of Test Facility

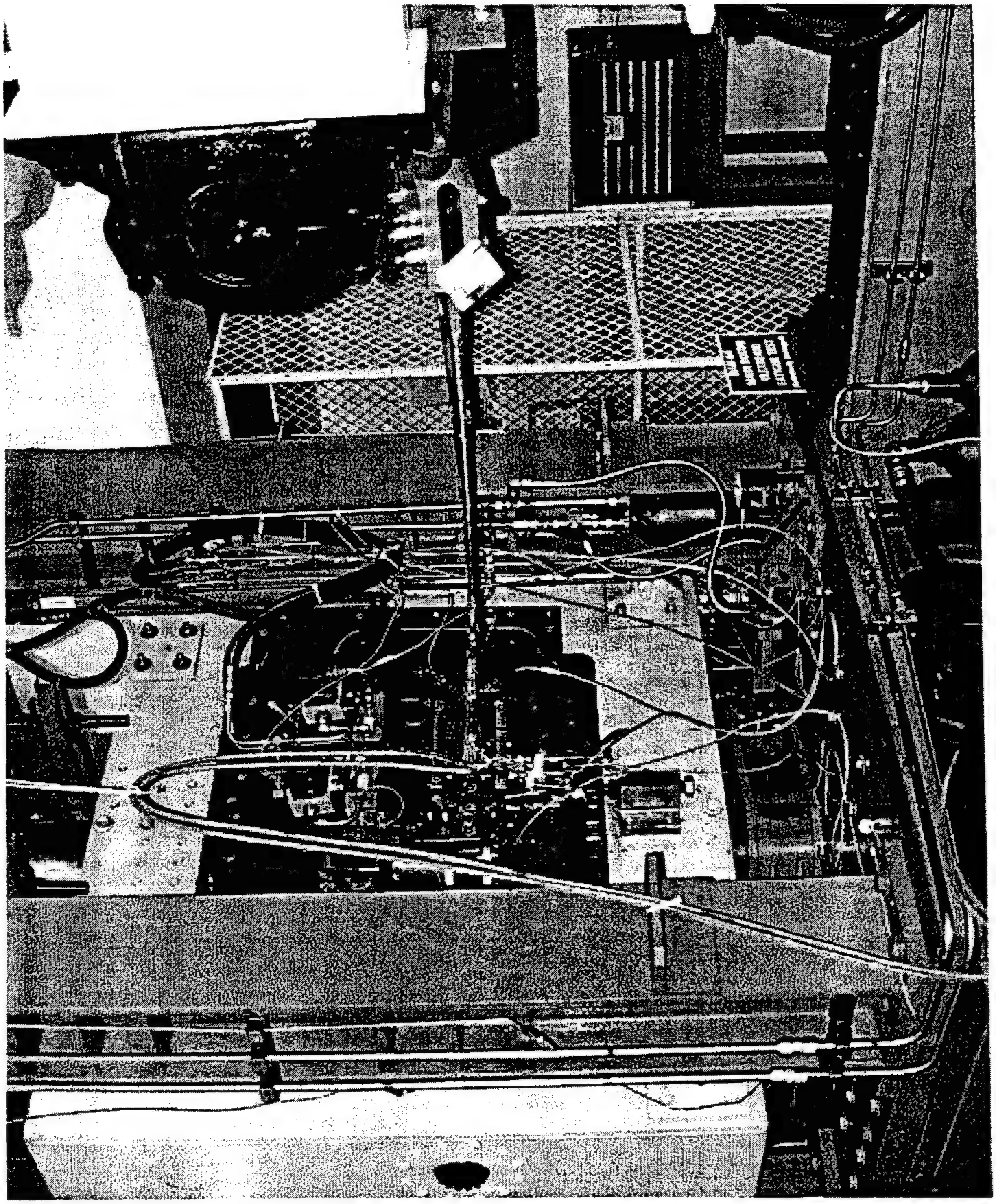

Figure 11 Picture of Ballistically Damaged Flexbeam in Test Facility

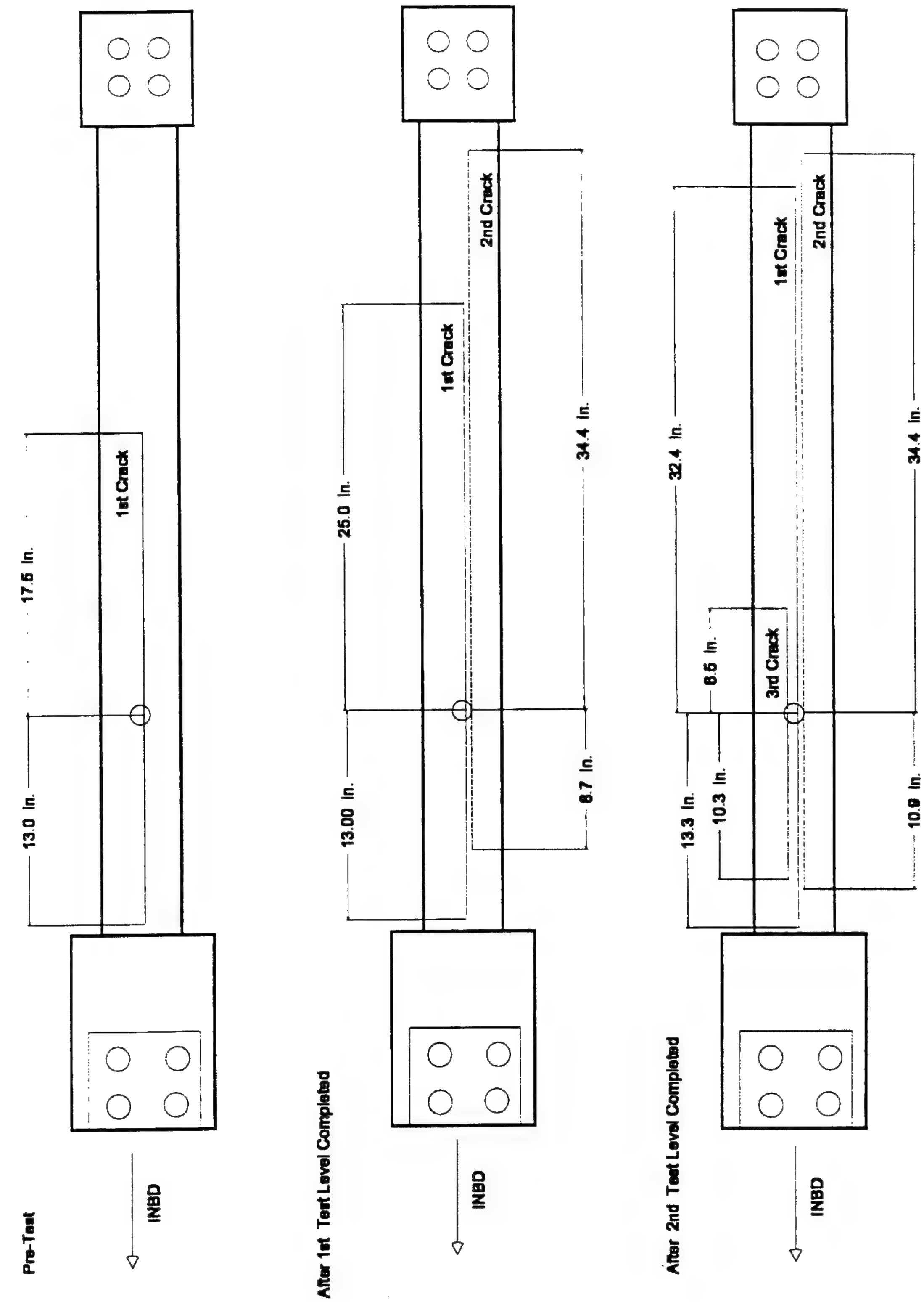

Figure 12 Flexbeam Crack Propagation Sketch

Appendix A

Pictures of Ballistically Damaged Flexbeam
after Completing First Load Level Testing